

NASA Facts

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Space Shuttle Solid Rocket Booster Retrieval Ships



A retrieval ship arrives at a half-submerged solid rocket booster after a Shuttle launch. Divers will prepare the SRB under water to float horizontally and be towed back to Port Canaveral.

To make Space Shuttle launches as economical as possible, the reuse of flight hardware is crucial. Unlike rocket boosters previously used in the space program, the Space Shuttle's solid rocket booster (SRB) casings and associated flight hardware are recovered at sea. The expended boosters are disassembled, refurbished and reloaded with solid propellant for reuse.

The Ships and Crew

The two retrieval ships which perform the SRB recovery, the *Liberty Star* and *Freedom Star*, are unique vessels specifically designed and constructed for this task. *Freedom Star* and *Liberty Star* are owned by NASA. They were built at Atlantic Marine Shipyard, Fort George Island, near Jacksonville, Fla., in 1980 and 1981*. The ships are 176 feet (53.6 meters) in length, 37 feet (11.2 meters) in width, and draw about 12 feet (3.6 meters) of water. Each ship displaces 1,052 tons (957 metric tons).

Each ship is propelled by two main engines providing a total of 2,900 horsepower. The main engines turn two seven-foot (2.1-meter) propellers with controllable pitch, which provides greater response time and maneuverability.

The ships also are equipped with two thrusters. The stern thruster is a water jet system that allows the ship to move in any direction without the use of propellers. This system was installed to protect the endangered manatee population that inhabits regions of the Banana River where the ships are based. The system also allows divers to work near the ship during operations at a greatly reduced risk.

Improvements have been made to the ships since they first began service. In addition to controllable pitch propellers, both vessels are now outfitted with highly precise Differential and WAAS Global Positioning System (GPS) navigational equipment, a Flume Tank System for increased stability, state-of-the-art communication systems, and man-rated SOLAS approved boat davits.

The ship's complement includes a crew of ten, a nine-person SRB retrieval team and a retrieval supervisor, plus observers. The maximum complement is 24 persons.

The Shuttle Solid Rocket Boosters

The typical Shuttle flight trajectory takes the vehicle away from the continental United States and over the Atlantic Ocean. Power is provided by the

combination of the orbiter's three main engines and the twin SRBs.

A pair of SRBs, fully loaded with propellant, weigh about 1.4 million pounds (635,040 kilograms) apiece. They stand 149.2 feet (45.5 meters) tall, and have a diameter of 12 feet (3.6 meters). The boosters in use today are the largest solid propellant motors ever developed for space flight and the first to be used on a manned space vehicle. These boosters will propel the orbiter to a speed of 3,512 miles per hour (5,652 kilometers per hour).

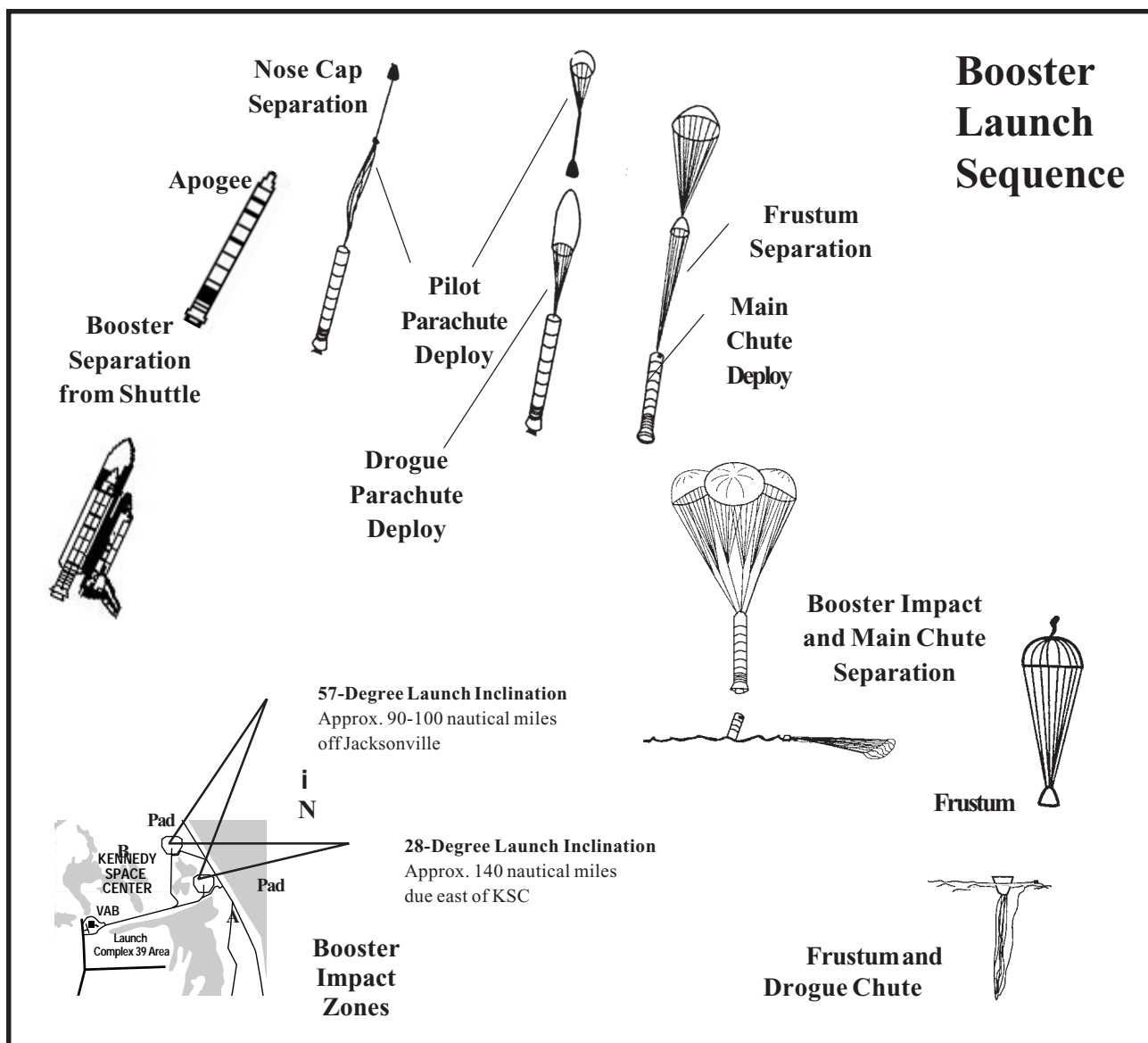
At about two minutes after the Space Shuttle lifts off from the launch pad, the twin SRBs have expended their fuel. The boosters separate from the orbiter and its external tank at an altitude of about 30.3 statute miles (26.3 nautical miles/48.7 kilometers) above the Earth's surface. After separation, momentum will propel the SRBs for another 70 seconds to an altitude of 44.5 statute miles (38.6 nautical miles/71.6 kilometers) before they begin their long tumble back to Earth.

SRB Descent and Splashdown

The nose cap of each booster is jettisoned at an altitude of 2.9 statute miles (2.5 nautical miles/4.6 kilometers) and deploys the pilot parachute. The pilot parachute immediately deploys the drogue parachute which is attached to the top of the frustum, the cone-shaped structure at the forward end of the booster.

At an altitude of 1.3 statute miles (1.1 nautical miles/2.1 kilometers), the frustums separate from the boosters. This releases three main parachutes housed within the frustums. It is these chutes that will quickly slow the booster's speed from 230 miles per hour (370.1 kilometers an hour) to a speed of 51 miles per hour (82.1 kilometers per hour). At approximately seven minutes after liftoff, the boosters will impact the Atlantic Ocean. The splashdown area is a box of about 6.9 by 10.4 statute miles (six by nine nautical miles/11.1 by 16.7 kilometers) located about 140 nautical miles (160 statute miles/257.6 kilometers) downrange from the launch pad.

The retrieval ships are on station at the time of splashdown, at about 9.2-11.5 statute miles (8-10 nautical miles/14.8-18.5 kilometers) from the impact area. As soon as the boosters enter the water, the ships accelerate to a speed of 15 knots (17.3 miles/27.8 kilometers an hour) and quickly close on the boosters.



Mission Event	Elapsed Time After Liftoff	Height (feet/meters)	Speed (miles/kilometers per hour)
Booster separation from Shuttle	124 seconds	156,000 feet (47,549 meters)	
Apogee (maximum height booster reaches after separation)	196 seconds	238,000 feet (72,542 meters)	
Nose cap separation/pilot chute deploy	349 seconds	16,000 feet (4,877 meters)	360 mph (579 kph)
Drogue chute deploy	350 seconds	15,530 feet (4,734 meters)	
Frustum separation/main chute deploy	371 seconds	6,450 feet (1,966 meters)	250 mph (402 kph)
Booster impact and main chute separation	414 seconds		50 mph (81 kph)
Frustum/drogue chute impact	459 seconds		40 mph (64 kph)



(Top left & right) The ship locates the booster,
divers separate the chutes;
(left) the ship retrieves the chutes.



(Above) Divers insert an Enhanced Diver-
Operated Plug into the booster nozzle,
displacing the water and causing the
booster to assume a semi-log or
horizontal position.



(Above left) The drogue chute is wound onto a
reel on deck. (Left) The frustum is lifted from
the water by a power block attached to the
ship's deck crane.



(Left) Divers attach tow lines to the floating booster.



With the booster now alongside in the hip tow position (right), the ship passes through a drawbridge and Canaveral Locks to the Banana River on its way to Hangar AF.

Retrieval

Each ship retrieves one booster. Upon arrival, the team first conducts a visual assessment of the flight hardware. The pilot chute and main parachutes are the first items to be brought on board. Their shroud lines are wound onto each of three of the four reels on the ship's deck. The drogue parachute, attached to the frustum, is reeled onto the fourth reel until the frustum is approximately 50 feet astern of the ship. The 5,000-pound (2,268-kilogram) frustum is then lifted from the water using the ship's power block and deck crane.

With the chutes and frustum recovered, attention turns to the SRB. The dive team prepares for booster recovery. Two small Ambar boats, with eight retrieval divers aboard, are deployed. The job of the first dive team is to install an Enhanced Diver-Operated Plug (EDOP) in the nozzle of the booster. The EDOP is launched from the ship and towed to the booster by one of the small boats. An air hose is then deployed from the ship. Once dive preparations are complete, the dive team enters the water for EDOP insertion. The EDOP is 22 feet (6.7 meters) in length and weighs 1,100 pounds (498 kilograms). It is neutrally buoyant in water, meaning it neither floats nor sinks, and is easily guided to the aft skirt at a depth of about 110 feet (33.5 meters) by the divers. A quick inspection of the nozzle

is conducted. The EDOP is then inserted into the booster nozzle. Once the EDOP legs are locked in place and the nozzle sealed, an air hose is attached.

The second team double-checks the aft skirt and EDOP installation to ensure there are no problems. After the second dive is completed, dewatering operations begin. Air is pumped from the ship through the EDOP and into the booster, displacing water within the casing. As the process continues, the booster rises in the water until it becomes top-heavy. It falls horizontally, like a log in the water. Air pumping continues until all water is expelled from the empty casing.

The final step in the ocean retrieval procedure is to connect the ship's tow line. Once the tow connection is made, the divers return to the ship and the trip to NASA's Hangar AF on Cape Canaveral Air Station begins.

The ships enter Port Canaveral, where the booster is changed from the stern tow position to a position alongside the ship, the hip tow position, to allow greater control. The ships then pass through a drawbridge, Canaveral Locks, and transit the Banana River to Hangar AF. They are lifted from the water with Straddle-Lift cranes and placed on rail cars to begin the disassembly and refurbishment process.



Freedom Star: The NASA "meatball" insignia was painted on the booster retrieval ships in 1992.



At Hangar AF, the booster is released from the ship. It will be towed to a position where Straddle-Lift cranes can lift it from the water and place it on a rail car for disassembly.

Ship Specifications

Length: 176 feet (53.6 meters)

Beam: 37 feet (11.3 meters)

Depth: 15 feet (4.6 meters) (From main deck to keel bottom)

Draft: 12 feet (3.6 meters)

Construction: Molded steel hull

Main propulsion: Two General Motors (EMD) 12-645E6A diesel engines, combined 2,900 horsepower, with Lufkin gears and LIPS controllable pitch propellers

Auxiliary propulsion: One 425-horsepower White Gill water jet stern thruster, driven by 8V71 turbo-intercooled (TI) Detroit diesel engine

Maneuvering: One 425-horsepower Schottel bow thruster, driven by 8V71 turbo-intercooled (TI) Detroit diesel engine

Ship's power: Two 166-kilowatt Kato generators and one 4-kilowatt Kohler emergency generator

Towing pull: 60,000 pounds (30 tons, or 27,216 kilograms)

Displacement: 1,052 tons (955 metric tons)

Normal cruising speed: 15 knots (17 miles/ 28 kilometers per hour)

Range: 6,900 miles (11,104 kilometers)

Endurance: Food and water for 30 days

Complement: 10 crew and 10-person retrieval team, plus observers. Total berthing: 24 persons

Retrieval support equipment: Primary and backup Enhanced Diver-Operated Plug and associated dewatering gear; one Sullair Rotary air-cooled, air compressor (for nozzle plug operation); UHF, VHF, HF and SATCOM communications equipment; one North American deck crane, five-ton (4.5-metric ton) capacity (for frustum retrieval); four parachute reels; one towing winch and one H-bit (for securing tow line) for towing one SRB casing with nozzle; one air hose reel.

Ships provide new service

In 1998 the solid rocket booster recovery ships took on a new service for NASA. Space Flight Operations contractor United Space Alliance streamlined efforts for the Space Shuttle program by taking over the towing of the Shuttle's external tanks from Louisiana to Florida using the *Liberty Star* and the *Freedom Star*. The new service makes better use of the ships' downtime between Shuttle launches.

The voyage begins near New Orleans at the Michoud Space Systems Assembly Facility where the external tanks are manufactured. Five days later, the ship and tank arrive at Port Canaveral where a conventional tugboat takes over for the tank's transit upriver to the KSC Launch Complex 39 turn basin.

To withstand the towing burden, the recovery ships had to undergo deck-strengthening enhancements. The stern was strengthened at critical points, new bulwark fairings were added, and an H-bitt was installed through which cabling is threaded to keep it centered during towing operations. Also installed was a hydraulic towing winch, referred to as a double-drum waterfall winch, holding 2,000 feet or more of wire rope on each drum. One drum supports booster retrievals while the other is devoted to external tank towing.



Freedom Star tows a barge with an external tank into Port Canaveral for the first time.

The recovery ship *Freedom Star* made the inaugural tow on June 16, 1998. The second recovery ship, *Liberty Star*, was refitted shortly after.

Other Applications

Well suited for their role supporting Space Shuttle operations, the *Liberty Star* and *Freedom Star* also have proven themselves in other operations. Over the years, both vessels have seen service in side-scan sonar operations, cable-laying, underwater search and salvage, drone aircraft recovery, as platforms for robotic submarine operations and numerous support roles for other government agencies. They have a proven record of reliability and performance.



Booster retrieval operations are controlled from the aft bridge of the ship (left photo). Equipment located here includes hookups for communicating with the divers, forward deck, and the other retrieval ship, wind gauge, stern/bow thruster controls and radar. The forward area of the bridge (right photo) is for operation of the ship itself. Such state-of-the-art equipment as the Global Positioning System for precise navigation is located here.